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“Integrated Wind Turbine Design”

WMC5MW laminate lay-out of reference blade for WP 3

AUTHOR:	R. Nijssen
AFFILIATION:	Knowledge Centre Wind turbine Materials and Constructions
ADDRESS:	Kluisgat 5, 1771 MV Wieringerwerf, the Netherlands
TEL.:	+31-(0)227-504927
EMAIL:	r.p.l.nijssen@wmc.eu
FURTHER AUTHORS:	G.D. de Winkel, J.M. Peeringa
REVIEWER:	WP3.1 members
APPROVER:	

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STATUS, CONFIDENTIALITY AND ACCESSIBILITY									
Status				**Confidentiality**				**Accessibility**	
S0	Approved/Released			**R0**	General public			Private web site	**X**
S1	Reviewed			**R1**	Restricted to project members			Public web site	
S2	Pending for review			**R2**	Restricted to European. Commission			Paper copy	
S3	Draft for commends	**X**		**R3**	Restricted to WP members + PL	**X**			
S4	Under preparation			**R4**	Restricted to Task members +WPL+PL				

PL: *Project leader* **WPL:** *Work package leader* **TL:** *Task leader*

1. Introduction

For the subcomponent subtask, the description of a reference turbine blade was expected to be useful for:

- estimating representative stresses and strains for subcomponents;
- identifying 'hotspots' in blade, i.e. areas of interest to represent with a subcomponent.

This document gives a description of the reference blade in terms of laminate structure.

The reference blade is based on the blade data in the UPWIND reference wind turbine description (URT) [1], as well as a representative laminate distribution made available by WMC (WMC5MW). Both are originally based on models of the LMH 64.5 meter blade, which have been used –with various small modifications- in projects such as DOWEC [2], MANGROVE e.g.[3], and NREL baseline turbine.

It should be noted, that the section properties of the URT are not 100% interconsistent. There are some differences in mass and (especially torsional) stiffness distribution, which are explored in [4].

For the purposes of WP3, the extra effort associated with redefining the laminate lay-out to better match the URT property distributions is at least postponed. The first reason is, that URT is subject to continuous modification. Secondly, the laminate properties are now based on OPTIMAT UD properties [5] and might be replaced with UPWIND reference material properties. Third, the URT blade description is formulated for full turbine (dynamic) simulations, whereas the WMC5MW description is mainly used for the purposes described above. Any differences between the two are not expected to lead to significant problems at this stage of the project.

2. WMC5MW description

The WMC5MW structural description consists of the tables below with a description of the lay-up and the laminate properties. The laminate properties are based on OPTIMAT and literature.

At each labeled rotor radius (the blade itself starts 2 m from the centre of the rotor), the number of layers and thicknesses at that location are given. In between labels, any ply drops are distributed linearly. Thus, the start and end of each layer is included implicitly to limit the size of the table.

EXAMPLE: AT 2 m radius, there are 106 layers of triax-2. The next line in this table (station B) is the same. So, between station A and B, there are 106 layers, which, together, are 100 mm thick. At station C, there are 28 layers left, so between B and C, 78 layers triax-2 are terminated (one by one, i.e. linear distribution of ply drops). Between C and D, there are 28 layers of triax, etc.

Not every layer starts from the blade root. Only layers triax 1, 2, and 3 have starting points at 2 m distance from the rotor centre = blade root.

3. URT description

The UPWIND reference turbine consists of a full turbine description and has been prepared in UPWIND WP1B1. The current version is version 9, and the blade structural properties are given in [1]. In WP2 also efforts have been made to create a detailed structural model for damping calculations [6].

4. References

[1] Various authors, 'UPWIND Reference Wind Turbine Version 009', September 2007, UPWIND WP3 site December 2007

[2] Lindenburg, C., 'Aeroelastic Analysis of the LMH64-5 Blade', ECN-C—03-020, June 2003, via www.ecn.nl

[3] Subroto, H., et al., 'Offshore wind turbine bottom founded steel support structure for the deeper waters of the northsea', proc. EWEC 2006, February 27th -March 2nd, Athens, Greece, 2006

[4] Peeringa, J.M., 'Comparison URT and WMC5MW.xls', UPWIND WP3 site, December 2007

[5] Nijssen, R.P.L. et al., 'OPTIMAT database', via www.wmc.eu

[6] E-mail conversations between members of WP3 and WP2, November/December, 2007

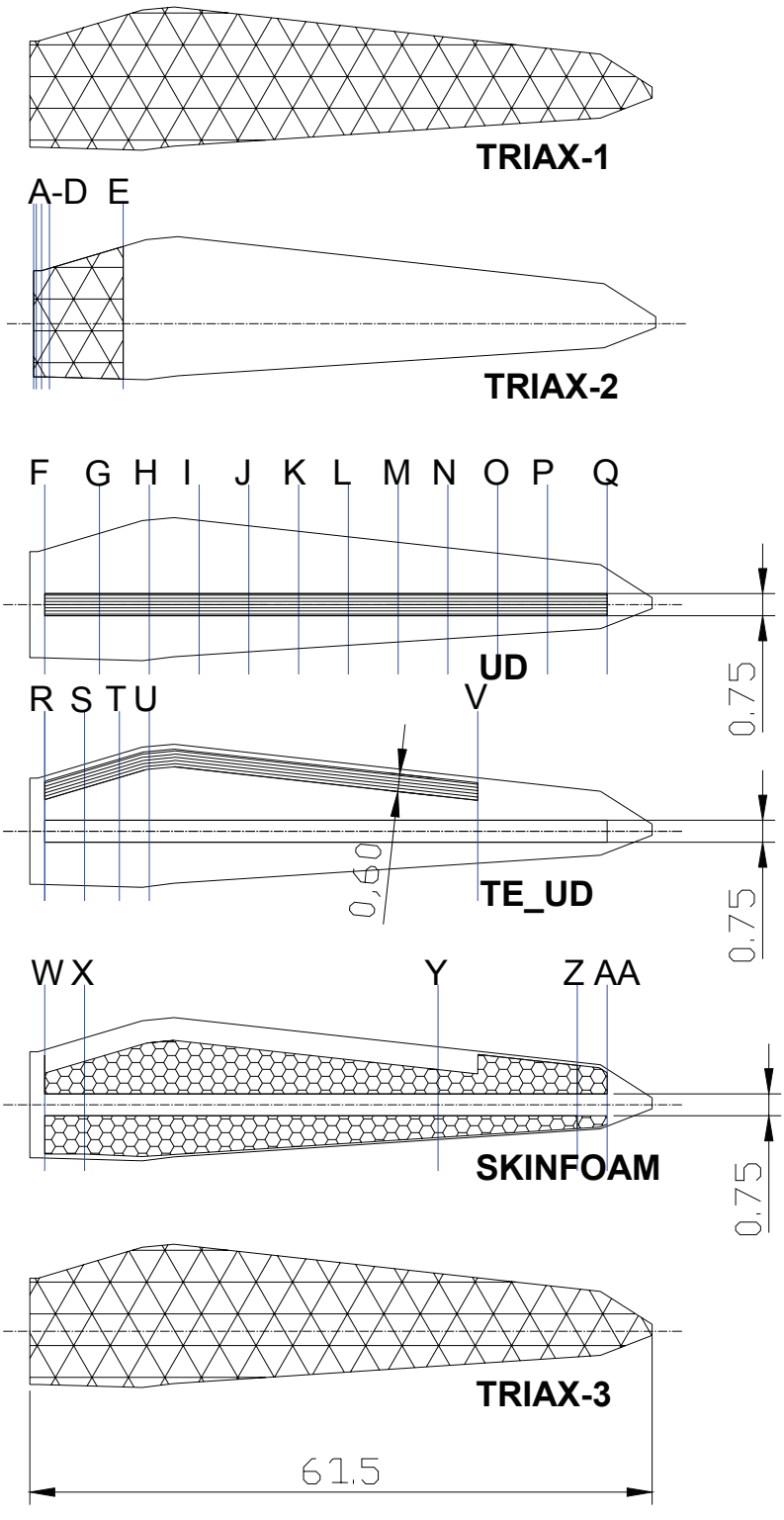
TRIAX-1
A-D E
TRIAX-2
F G H I J K L M N O P Q
UD
0.75
R S T U V
0,60
TE_UD
0.75
W X Y Z AA
SKINFOAM
0.75
TRIAX-3
61.5

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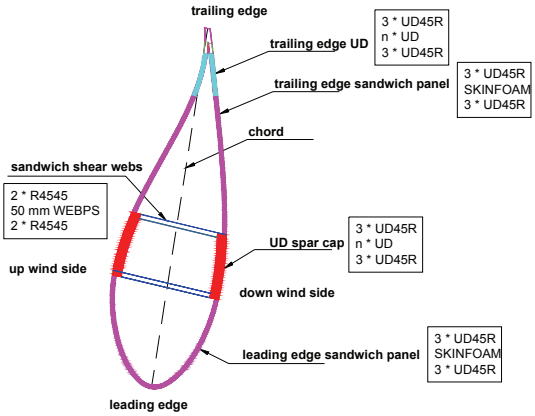
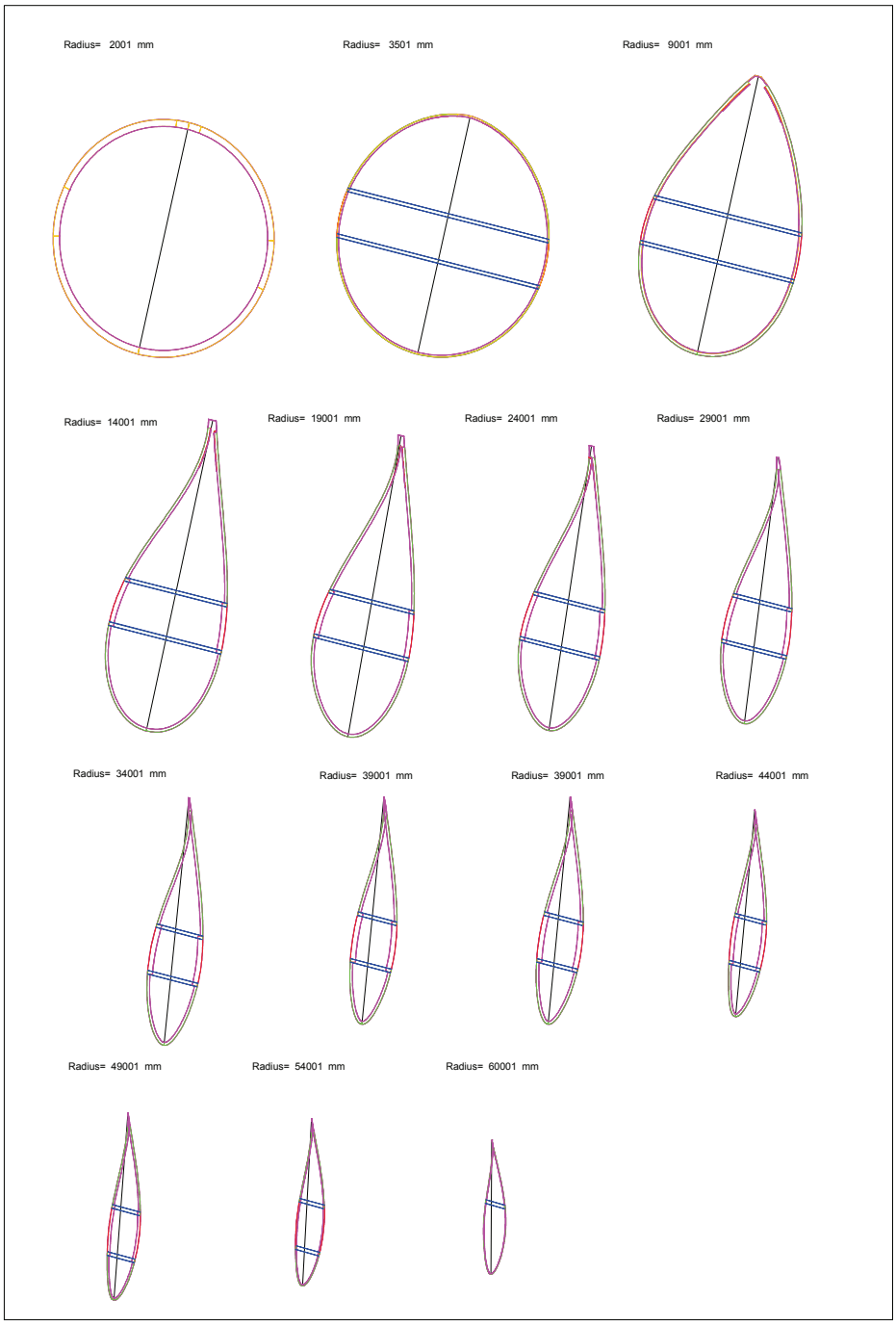
Table 1: Lay-up description

Layer ID	MATERIAL NAME	Label	Radius	Nr of layers	Thickness per layer	Total thickness
			[m]	[-]	[mm]	[mm]
TRIAX-1	UD45R		2.0	3	0.94	2.82
TRIAX-1	UD45R		63.5	3	0.94	2.82
TRIAX-2	UD45R	A	2.0	106	0.94	100.00
TRIAX-2	UD45R	B	2.3	106	0.94	100.00
TRIAX-2	UD45R	C	2.8	28	0.94	26.00
TRIAX-2	UD45R	D	3.6	28	0.94	26.00
TRIAX-2	UD45R	E	11.0	1	0.94	0.94
UD	UD_OB	F	3.5	1	0.47	0.47
UD	UD_OB	G	9.0	105	0.47	49.26
UD	UD_OB	H	14.0	205	0.47	96.33
UD	UD_OB	I	19.0	200	0.47	94.05
UD	UD_OB	J	24.0	186	0.47	87.37
UD	UD_OB	K	29.0	172	0.47	80.94
UD	UD_OB	L	34.0	153	0.47	71.77
UD	UD_OB	M	39.0	124	0.47	58.37
UD	UD_OB	N	44.0	99	0.47	46.45
UD	UD_OB	O	49.0	55	0.47	25.81
UD	UD_OB	P	54.0	21	0.47	9.99
UD	UD_OB	Q	60.0	1	0.47	0.47
UD_TE	UD_OB	R	3.5	1	0.47	0.47
UD_TE	UD_OB	S	7.5	32	0.47	15.0
UD_TE	UD_OB	T	11.0	45	0.47	21.0
UD_TE	UD_OB	U	14.0	29	0.47	13.6
UD_TE	UD_OB	V	47.0	1	0.47	0.47
SKINFOAM	SKINFOAM	W	3.5			1.00
SKINFOAM	SKINFOAM	X	7.5			40.00
SKINFOAM	SKINFOAM	Y	43.0			40.00
SKINFOAM	SKINFOAM	Z	57.0			6.00
SKINFOAM	SKINFOAM	AA	60.0			6.00
TRIAX-3	UD45R		2.0	3	0.94	2.82
TRIAX-3	UD45R		63.5	3	0.94	2.82

Table 2: Material properties

	E11	E22	G12	nu12	density	UTS (mean)	UCS (mean)
	[MPa]	[MPa]	[MPa]	[-]	[kg/m^3]	[MPa]	[MPa]
OD_OB	38887	9000	3600	0.249	1869	810	507
UD45R	24800	11500	4861	0.416	1826	436	349
R4545	11700	11700	9770	0.501	1782	180	144
SKINFOAM	256	256	22	0.3	200		
WEBPS	25	25	12	0.3	45		


trailing edge
trailing edge UD
3 * UD45R
n * UD
3 * UD45R
trailing edge sandwich panel
3 * UD45R
SKINFOAM
3 * UD45R
chord
sandwich shear webs
2 * R4545
50 mm WEBPS
2 * R4545
UD spar cap
3 * UD45R
n * UD
3 * UD45R
up wind side
down wind side
leading edge sandwich panel
3 * UD45R
SKINFOAM
3 * UD45R
leading edge


Radius= 2001 mm
Radius= 3501 mm
Radius= 9001 mm
Radius= 14001 mm
Radius= 19001 mm
Radius= 24001 mm
Radius= 29001 mm
Radius= 34001 mm
Radius= 39001 mm
Radius= 39001 mm
Radius= 44001 mm
Radius= 49001 mm
Radius= 54001 mm
Radius= 60001 mm